



# **OCO-2 Status**

## **April 24, 2018**

**Dave Crisp**

**Jet Propulsion Laboratory, California Institute of Technology  
for the OCO-2 Science Team**



# Overview

- **Observatory Status: Nominal**
  - Formation flying overlap expected to 100% through 18 June 2018
  - 2018 Inclination Adjust Maneuvers: 3 down, 1 to go (26 April)
- **Instrument Status: Nominal**
  - Most recent Decontamination Cycle conducted 13-20 February
- **Status of the CEOS Greenhouse Gas White Paper**
- **A first look at TanSat L2 data products**
  - Yang et al., Adv. Atmos. Sci., 35(6), 621–623, 2018
  - Yi Liu's EGU Presentation
- **A quick look at OCO-2 XCO<sub>2</sub> yields over tropical land**
- **Upcoming meetings**
  - EGU, CEOS SIT and AC-VC, IWGGMS-14, JpGU, AOGS, COSPAR

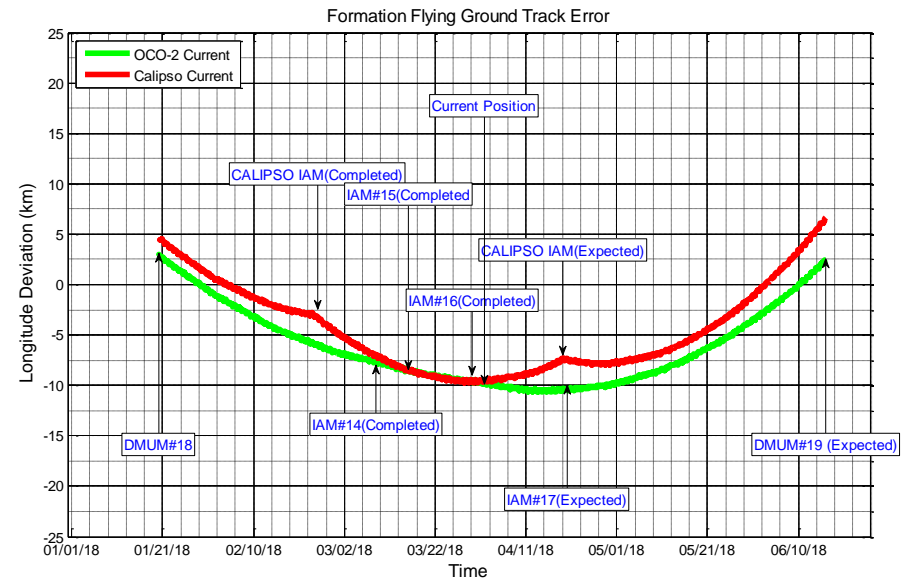
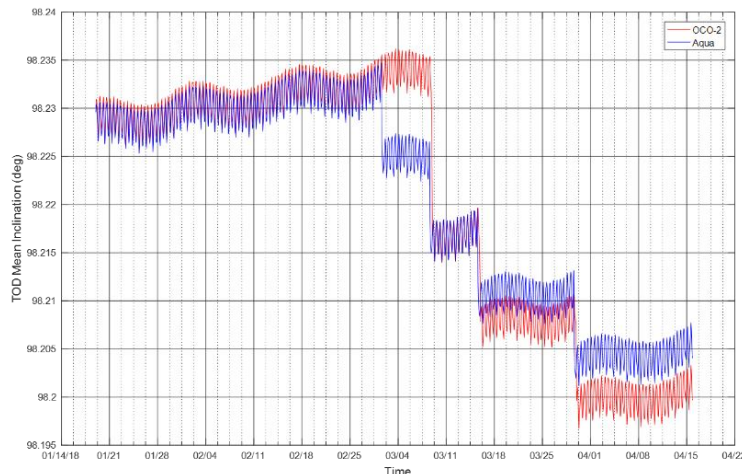


# OCO-2/CALIPSO Ground Track Overlap

Annual A-Train Inclination Adjust Maneuver campaign ongoing through 26 April.

- 01 March maneuver was cancelled due to orbital debris concerns
- 8, 15, 29 March maneuvers successful
- Campaign designed to maintain excellent overlap with CALIPSO ground track
- We lose 1-2 orbits of data for each maneuver.

Start Time (UTCG)	Stop Time (UTCG)
08 Mar 2018 21:42:06	08 Mar 2018 21:49:00
15 Mar 2018 21:49:38	15 Mar 2018 21:53:56
29 Mar 2018 22:02:06	29 Mar 2018 22:06:14
26 Apr 2018 22:27:48	26 Apr 2018 22:29:48



# **CEOS Greenhouse Gas White Paper**





# The CEOS Greenhouse Gas White Paper

A White Paper on Greenhouse Gas measurements from space is currently being drafted by the Committee on Earth Observation Satellites (CEOS) Atmospheric Composition – Virtual Constellation (AC-VC) team

## Executive Summary

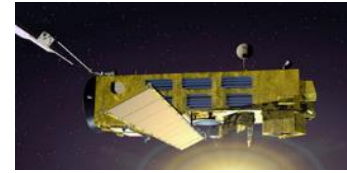
- 1: Introduction
  - 2: Using atmospheric GHG measurements to improve inventories
  - 3: Space-based GHG measurement capabilities and near term plans
  - 4: Lessons Learned from SCIAMACHY, GOSAT and OCO-2
  - 5: Integrating GHG Satellites into Operational Constellations
  - 6: Towards an operational constellation measuring anthropogenic CO<sub>2</sub> emissions
  - 7: The Transition from Science to Operations
  - 8: Conclusions
- Complete Draft  
Partial Draft  
Not Started

Please let me know if you would like to serve as an author or reviewer.



# *Remote Sensing of CO<sub>2</sub> and CH<sub>4</sub> using Reflected Sunlight: The Pioneers*

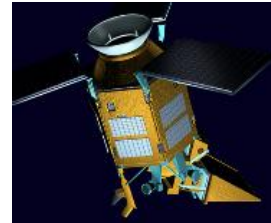
- **SCIAMACHY (2002-2012)** – First sensor to measure O<sub>2</sub>, CO<sub>2</sub>, and CH<sub>4</sub> using reflected NIR/SWIR sunlight
  - Regional-scale maps of X<sub>CO2</sub> and X<sub>CH4</sub> over continents
- **GOSAT (2009 ...)** – First Japanese GHG satellite
  - FTS optimized for high spectral resolution over broad spectral range, yielding CO<sub>2</sub>, CH<sub>4</sub>, and chlorophyll fluorescence (SIF)
- **OCO-2 (2014 ...)** – First NASA satellite to measure O<sub>2</sub> and CO<sub>2</sub> with high sensitivity, resolution, and coverage
  - High resolution imaging grating spectrometer small (< 3 km<sup>2</sup>) footprint and rapid sampling (10<sup>6</sup> samples/day)
- **TanSat (2016 ...)** - First Chinese GHG satellite
  - Imaging grating spectrometer for O<sub>2</sub> and CO<sub>2</sub> bands and cloud & aerosol Imager
  - In-orbit checkout formally complete in August 2017





# Remote Sensing of $\text{CO}_2$ and $\text{CH}_4$ : The Next Generation

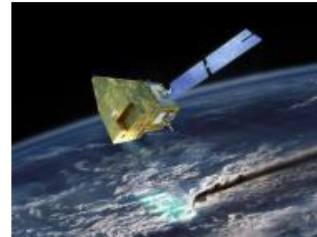
- **Feng Yun 3D (2017)** – Chinese GHG satellite on an operational meteorological bus
  - GAS FTS for  $\text{O}_2$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{CO}$ ,  $\text{N}_2\text{O}$ ,  $\text{H}_2\text{O}$
- **Sentinel 5p (2017)** - Copernicus pre-operational Satellite
  - TROPOMI measures  $\text{O}_2$ ,  $\text{CH}_4$  (1%),  $\text{CO}$  (10%),  $\text{NO}_2$ , SIF
  - Imaging at 7 km x 7 km resolution, daily global coverage
- **Gaofen 5 (2018)** - 2<sup>nd</sup> Chinese GHG Satellite
  - Spatial heterodyne spectrometer for  $\text{O}_2$ ,  $\text{CO}_2$ , and  $\text{CH}_4$
- **GOSAT-2 (2018)** – Japanese 2<sup>nd</sup> generation satellite
  - $\text{CO}$  as well as  $\text{CO}_2$ ,  $\text{CH}_4$ , with improved precision (0.125%), and active pointing to increase number of cloud free observation
- **OCO-3 (2019\*)** – NASA OCO-2 spare instrument, on ISS
  - First  $\text{CO}_2$  sensor to fly in a low inclination, precessing orbit





# Future GHG Satellites

- **CNES/UK MicroCarb (2021+)** – compact, high sensitivity
  - Imaging grating spectrometer for  $O_2 A$ ,  $O_2 \ ^1\Delta_g$ , and  $CO_2$
  - ~1/2 of the size, mass of OCO-2, with 4.5 km x 9 km footprints
- **CNES/DLR MERLIN (2021+)** - First  $CH_4$  LIDAR (IPDA)
  - Precise (1-2%)  $X_{CH_4}$  retrievals for studies of wetland emissions, inter-hemispheric gradients and continental scale annual  $CH_4$  budgets
- **NASA GeoCarb (2022\*)** – First GEO GHG satellite
  - Imaging spectrometer for  $X_{CO_2}$ ,  $X_{CH_4}$ ,  $X_{CO}$  and SIF
  - Stationed above North/South America
- **Sentinel 5A,5B,5C (2022)** - Copernicus operational services for air quality and  $CH_4$ 
  - Daily global maps of  $X_{CO}$  and  $X_{CH_4}$  at  $< 8 \text{ km} \times 8 \text{ km}$



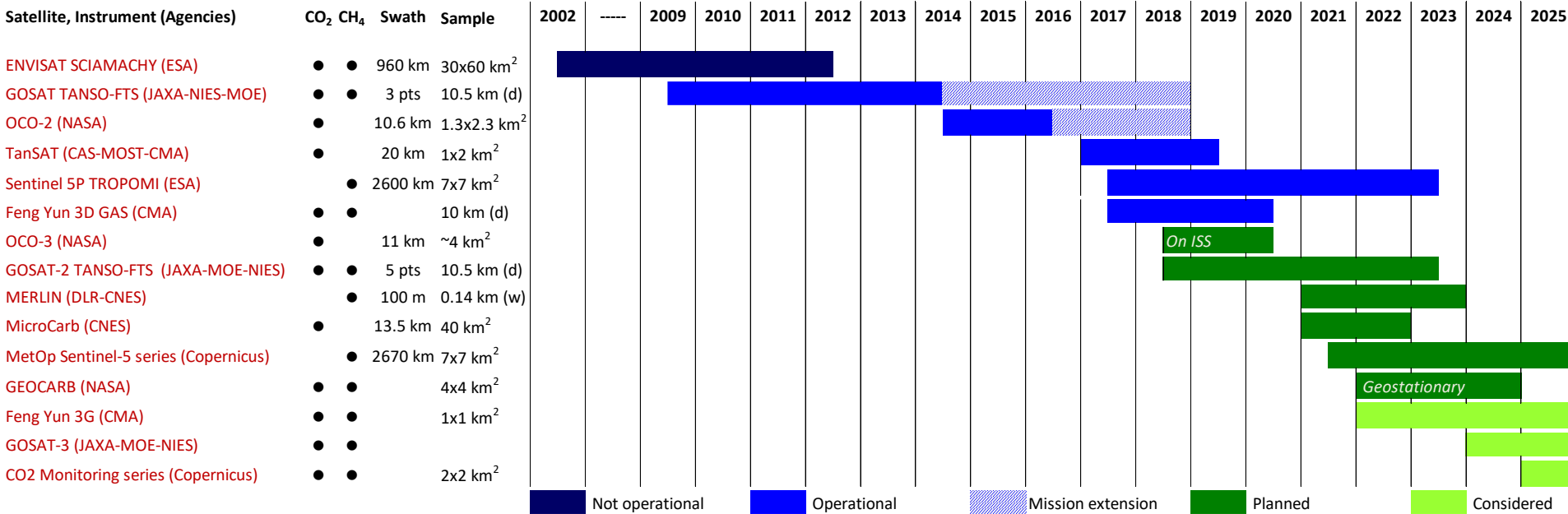


# Constellations in the Planning Stages

- **Copernicus Sentinel CO<sub>2</sub> (2025+)**
  - 3 or 4 LEO satellites in an operational GHG constellation
  - Primary instruments measure O<sub>2</sub> (0.76  $\mu\text{m}$  A-band), CO<sub>2</sub> (1.61 and 2.06  $\mu\text{m}$ ), and NO<sub>2</sub> (0.450  $\mu\text{m}$ ) at a spatial resolution of 2 km x 2 km along a broad (200-300 km) swath
  - A dedicated cloud/aerosol instrument is also under consideration
- **TanSat-2 Constellation**
  - 6 satellites, with 3 flying in morning sun-synchronous orbits and 3 flying in afternoon sun-synchronous orbits
  - primary GHG instrument on each satellite with measure CO<sub>2</sub> (1.61 and 2.06  $\mu\text{m}$ ), CH<sub>4</sub> and CO (2.3  $\mu\text{m}$ ) as well as the O<sub>2</sub> A-band (0.76  $\mu\text{m}$ ) across a 100-km cross-track swath



# GHG Mission Timeline



- A broad range of GHG missions will be flown over the next decade.
- Most are “science” missions, designed to identify optimal methods for measuring CO<sub>2</sub> and CH<sub>4</sub>, not “operational” missions designed to deliver policy relevant GHG products focused on anthropogenic emissions

# First Global $X_{\text{CO}_2}$ Maps from TanSat





# First Global XCO<sub>2</sub> Maps from TanSat

- The TanSat Team published the first global maps of XCO<sub>2</sub> over land as a 3-page New and Views article in Advances in Atmospheric Sciences

<https://link.springer.com/article/10.1007/s00376-018-7312-6>

- Two dot-plot maps were shown:
  - Nadir mode observations for April 2017
  - Nadir mode observations for July 2017
- Here, I've compared those results to the OCO-2 v8 dot plot maps for the same months
  - Global
  - North America zoom
  - Eurasia/Africa zoom



# Yang et al. *Advances in Atmospheric Sciences* (2018)



## First Global Carbon Dioxide Maps Produced from TanSat Measurements

Dongxu YANG<sup>1</sup>, Yi LIU<sup>\*1,2</sup>, Zhaonan CAI<sup>1</sup>, Xi CHEN<sup>1</sup>, Lu YAO<sup>1,2</sup>, and Daren LU<sup>1</sup>

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(Received 28 December 2017; revised 1 February 2018; accepted 13 February 2018)

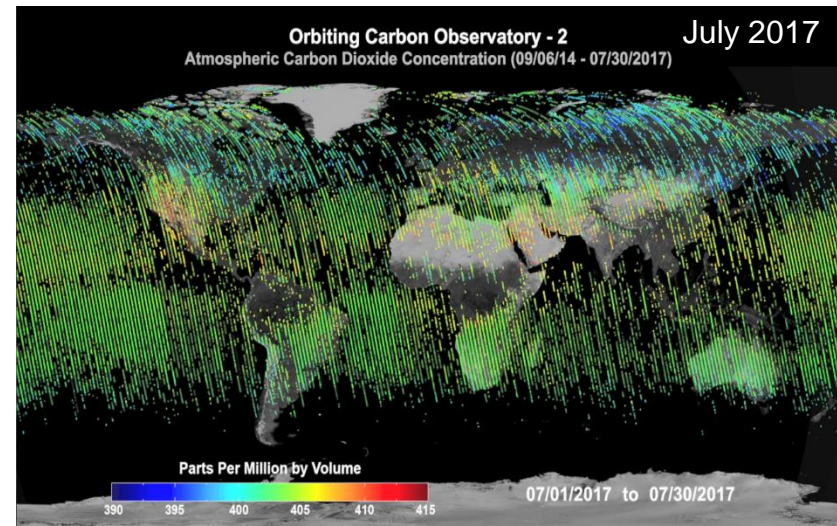
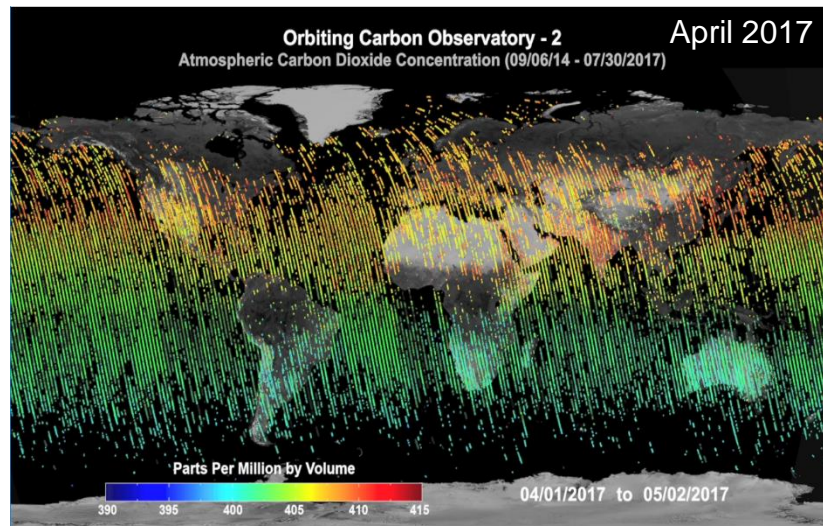
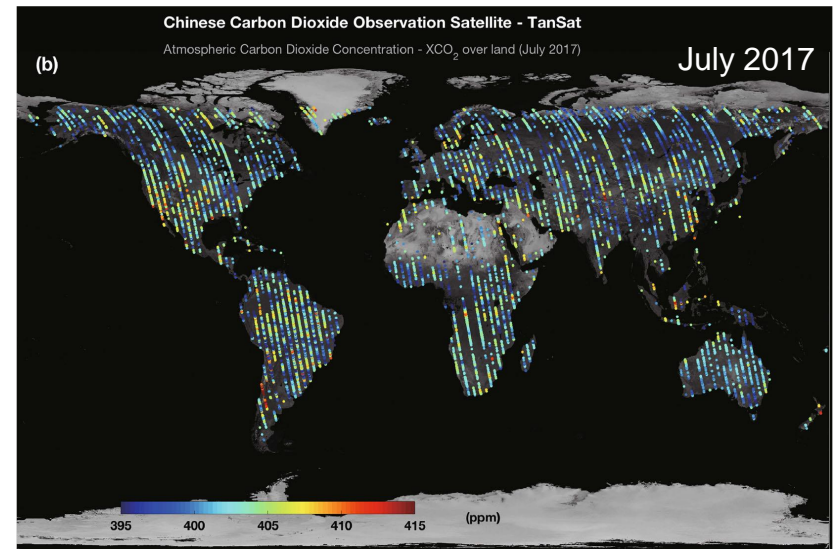
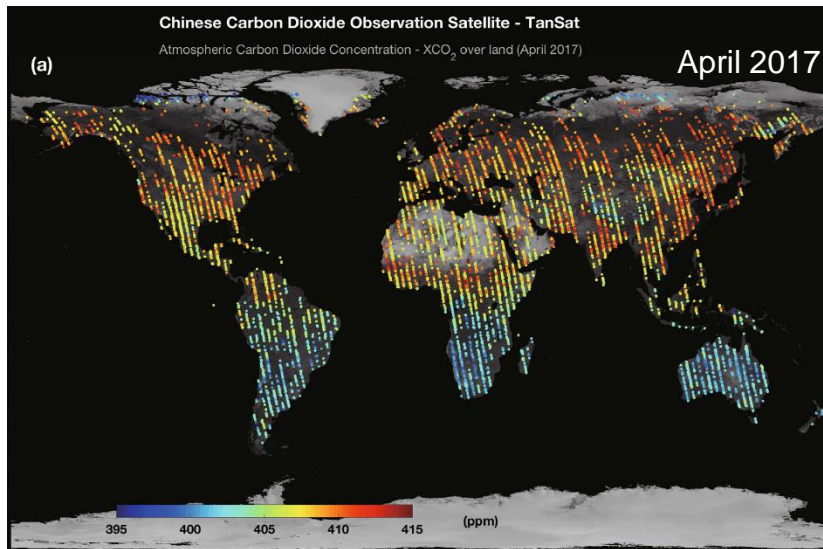
Citation: Yang, D. X., Y. Liu, Z. N. Cai, X. Chen, L. Yao, and D. R. Lu, 2018: First global carbon dioxide maps produced from TanSat measurements. *Adv. Atmos. Sci.*, 35(6), 621–623,  
<https://doi.org/10.1007/s00376-018-7312-6>.

or see:

<https://link.springer.com/article/10.1007/s00376-018-7312-6>

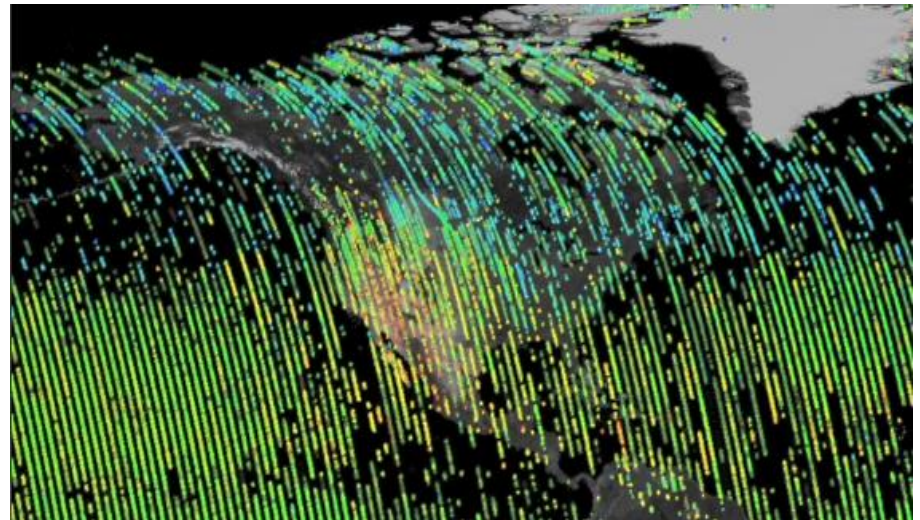
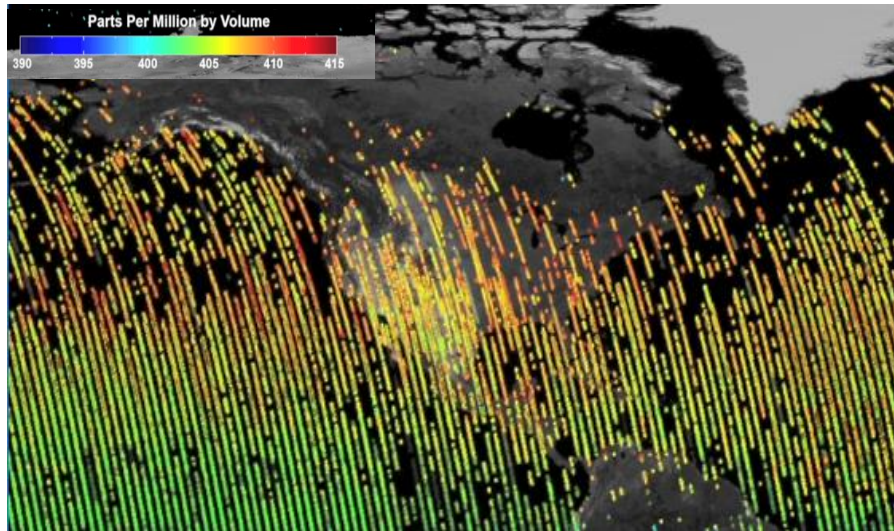
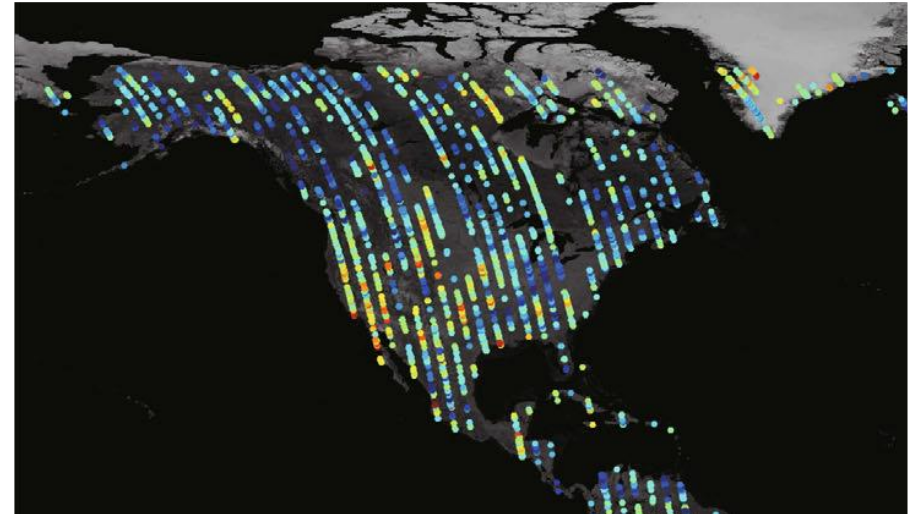
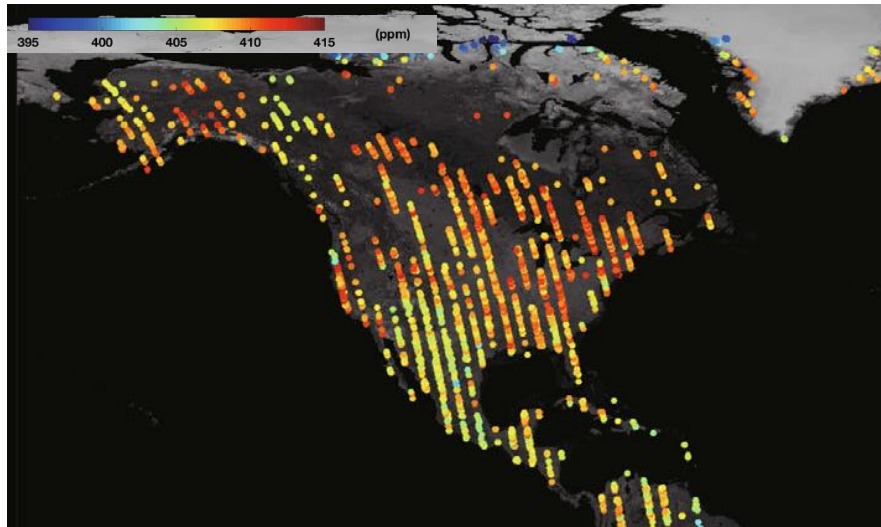


# TanSat (top) vs OCO-2 (bottom)



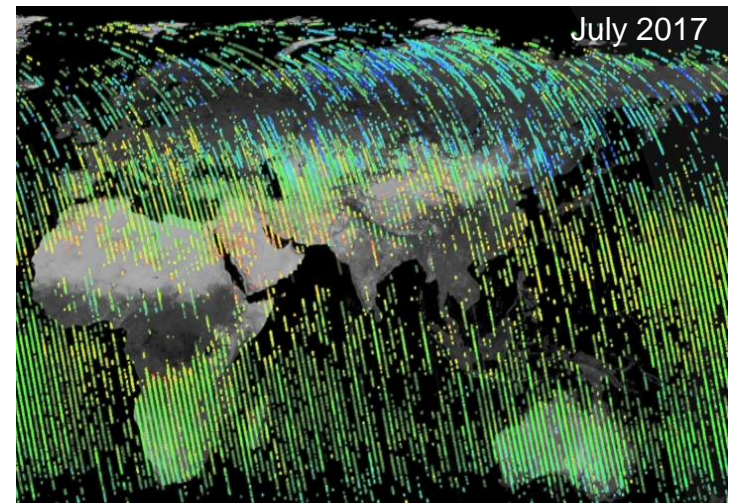
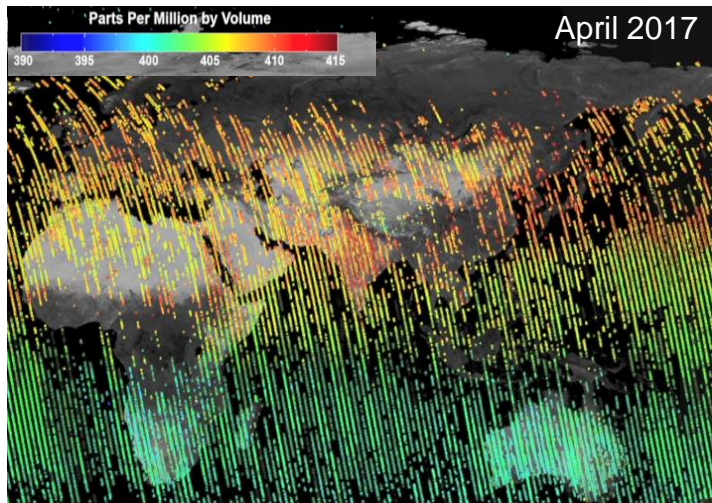
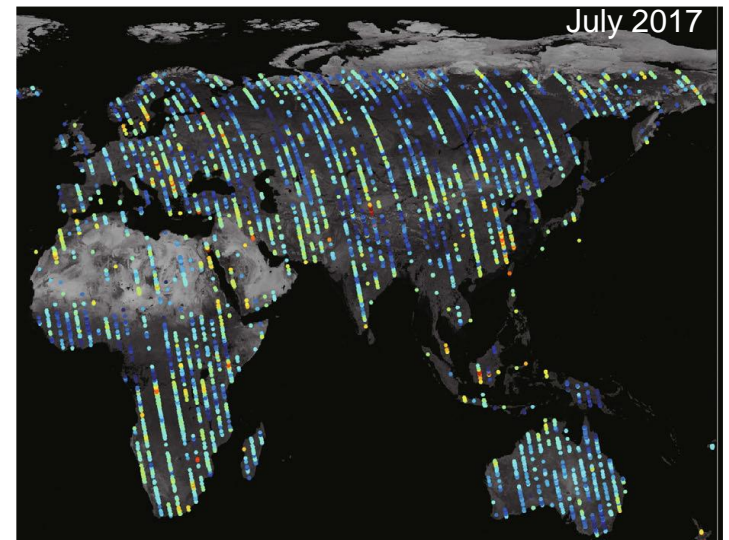
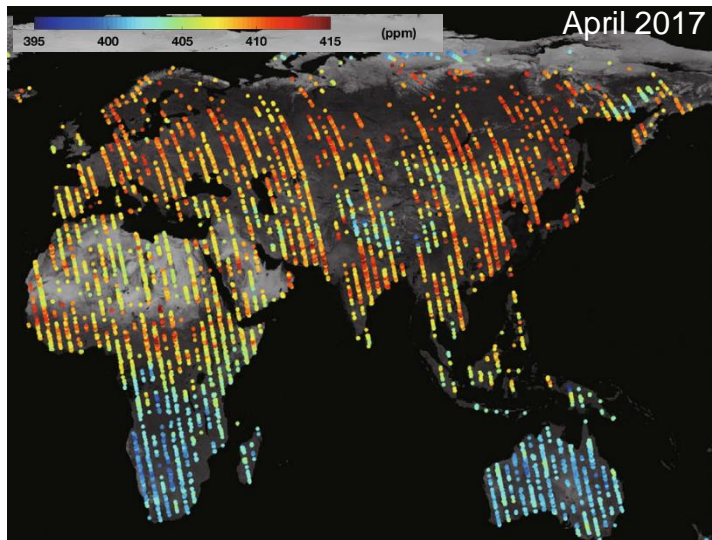


# TanSat (top) vs OCO-2 (bottom)



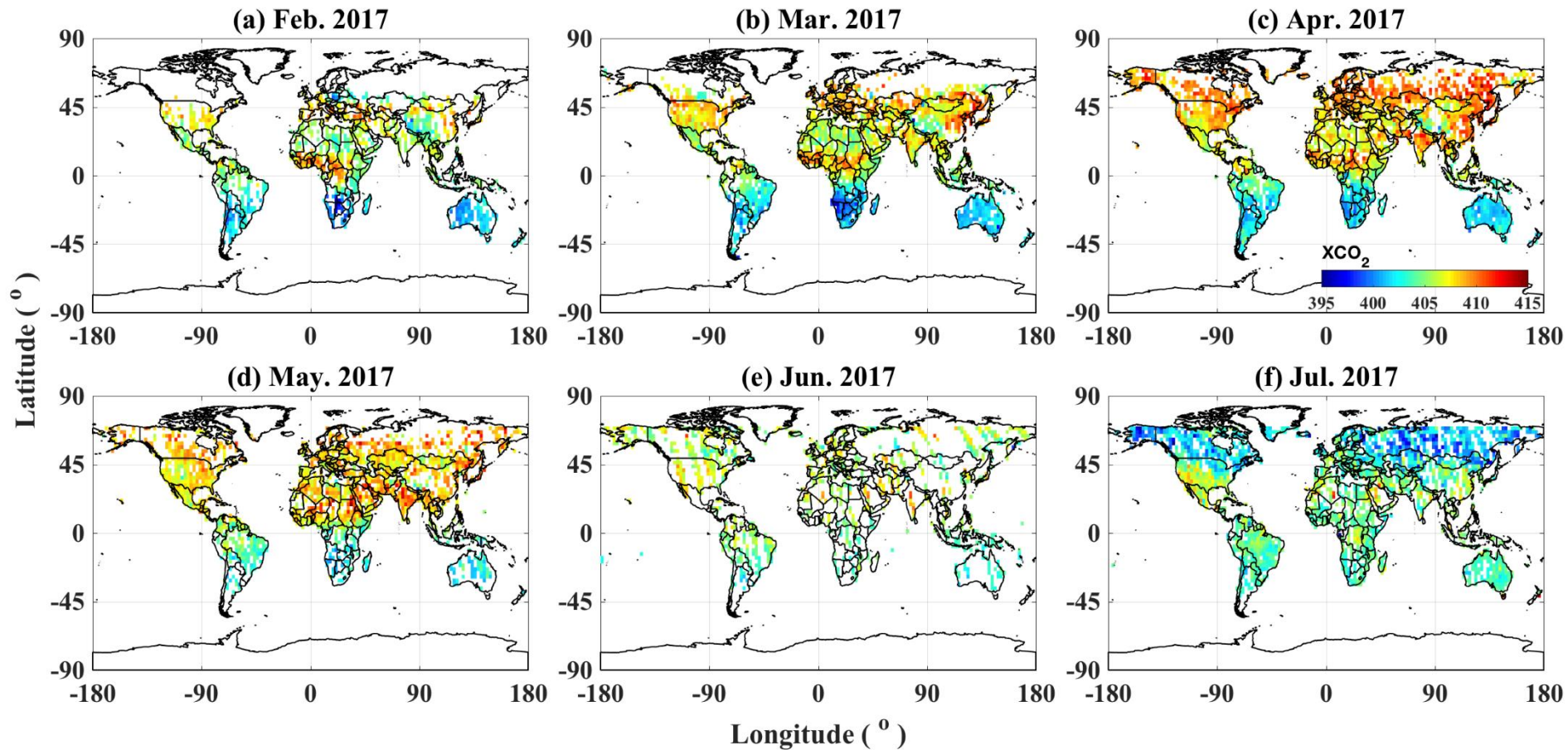


# TanSat (top) vs OCO-2 (bottom)





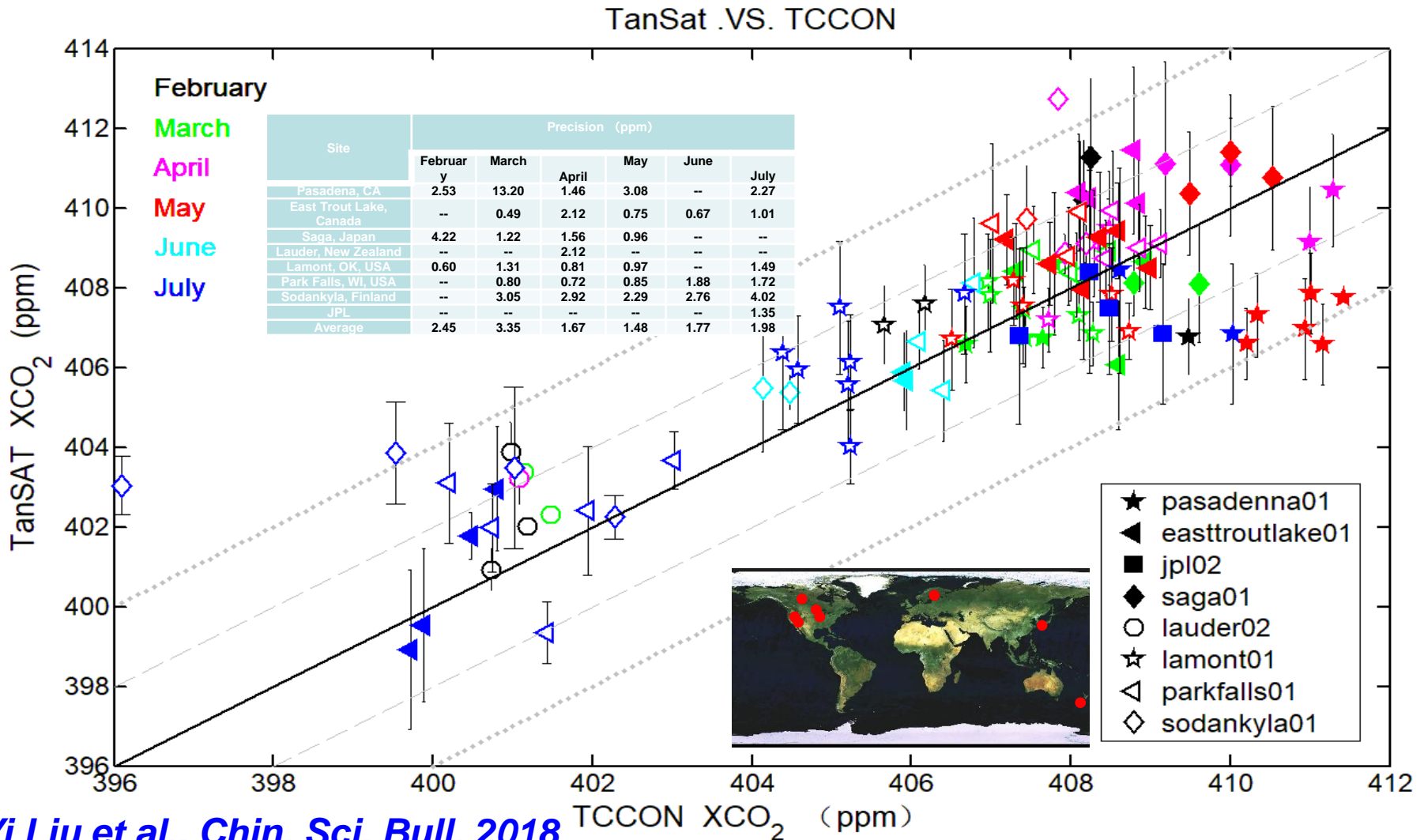
# The first 6 month TanSat XCO<sub>2</sub>



*Yi Liu et al., Chin. Sci. Bull. 2018*



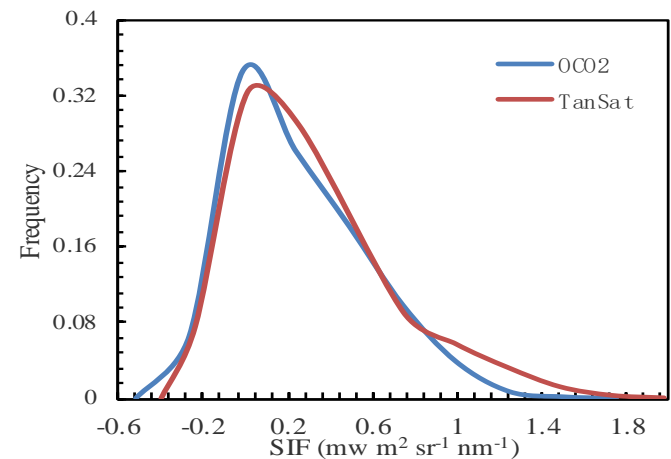
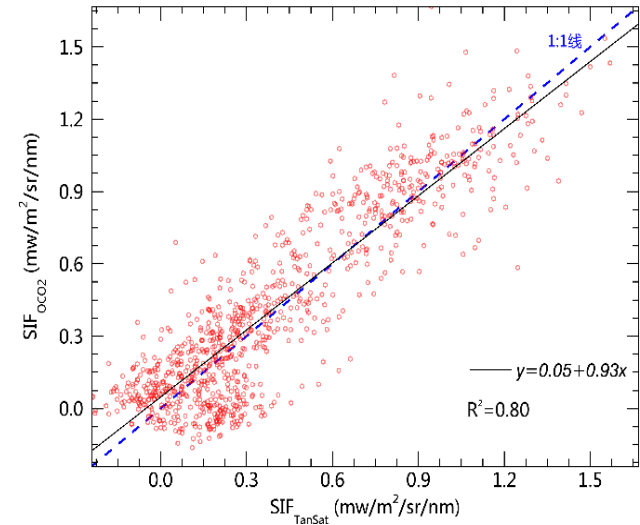
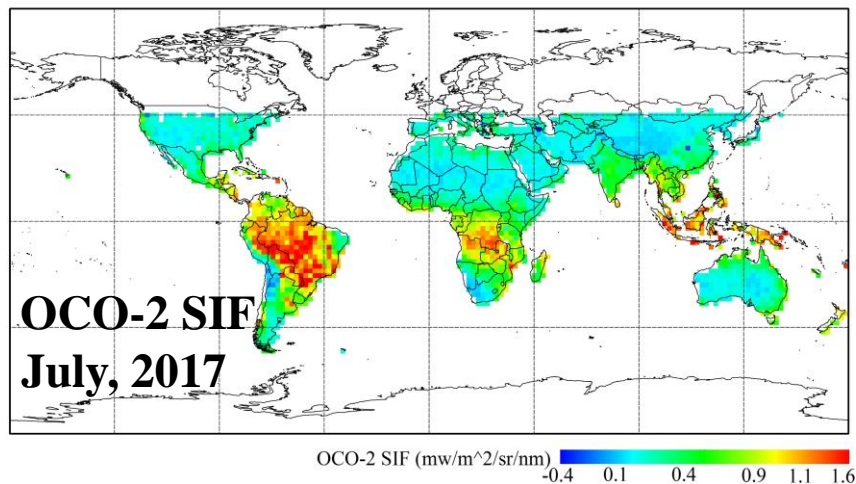
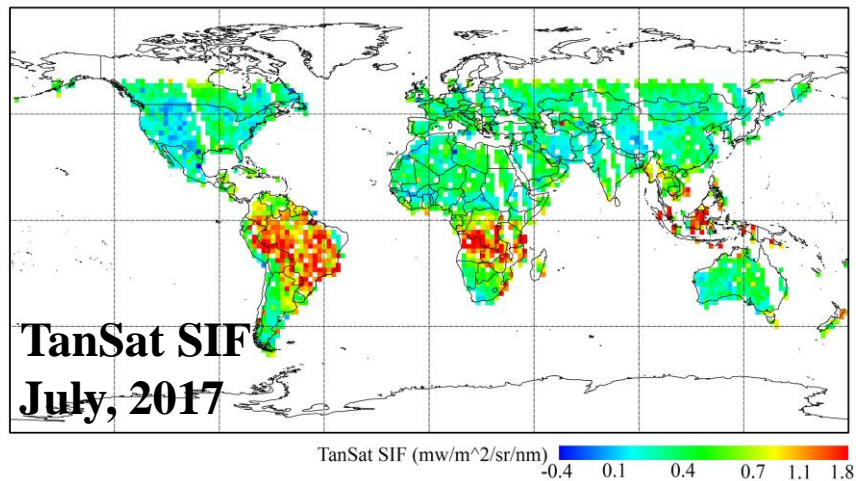
# TanSat XCO<sub>2</sub> validation against TCCON



Yi Liu et al., Chin. Sci. Bull. 2018



# Global terrestrial SIF map from TanSat observations



*Liangyun Liu et al., Chin. Sci. Bull. 2018*



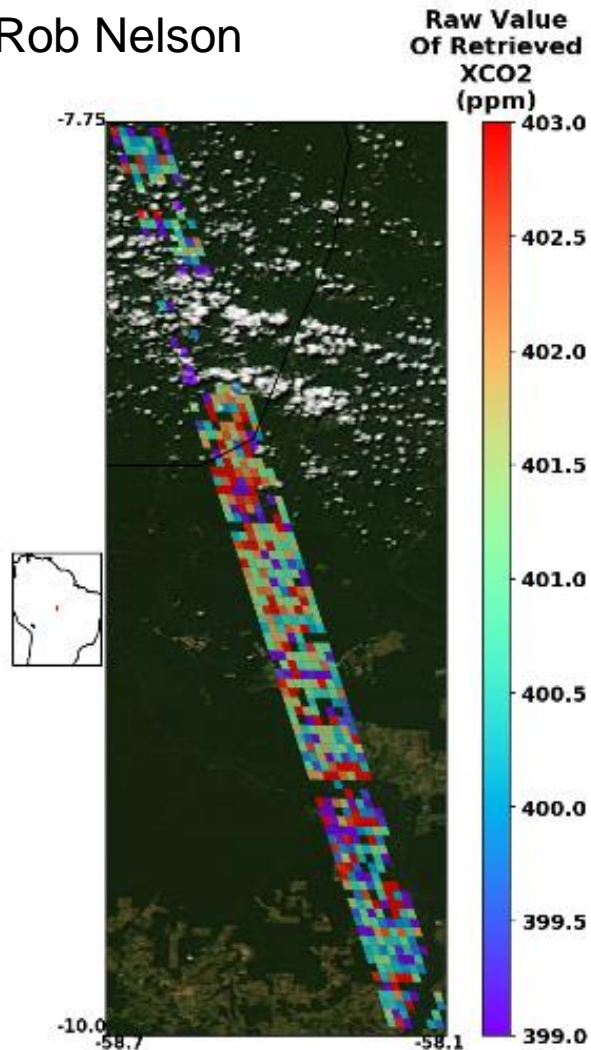
# Preliminary Assessment

- The OCO-2 and TanSat results are similar on regional scales
  - This what we would expect given that the two spacecraft have similar instruments and they are following nearby orbit tracks, separated by less than 50 minutes.
- There are differences in coverage
  - The OCO-2 data set includes glint and nadir, while only nadir data are shown for TanSat
    - OCO-2 covers land & ocean while the TanSat data covers only land
    - The OCO-2 tracks appear to be more closely spaced because the glint tracks are offset from the nadir tracks
  - The TanSat dataset has somewhat better coverage over
    - Amazon and over tropical Africa
    - High northern latitudes
  - These soundings are screened out of the OCO-2 v8 data
    - A track-by-track (WorldView) analysis would be needed to assess the quality of the additional TanSat soundings

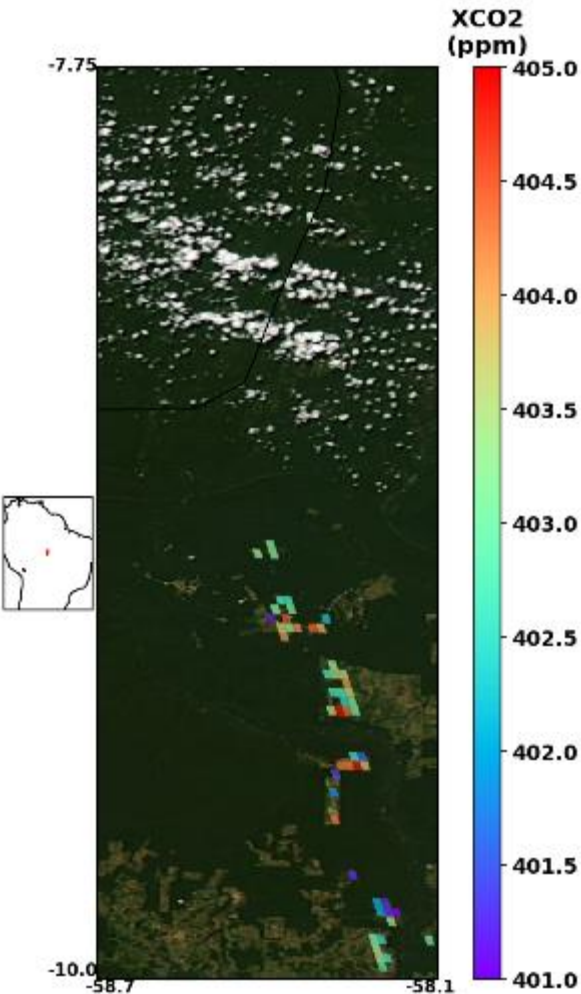


# Why is the OCO-2 Yield so Low over Tropical Land?

Rob Nelson



All Data (B8, latest lite files)



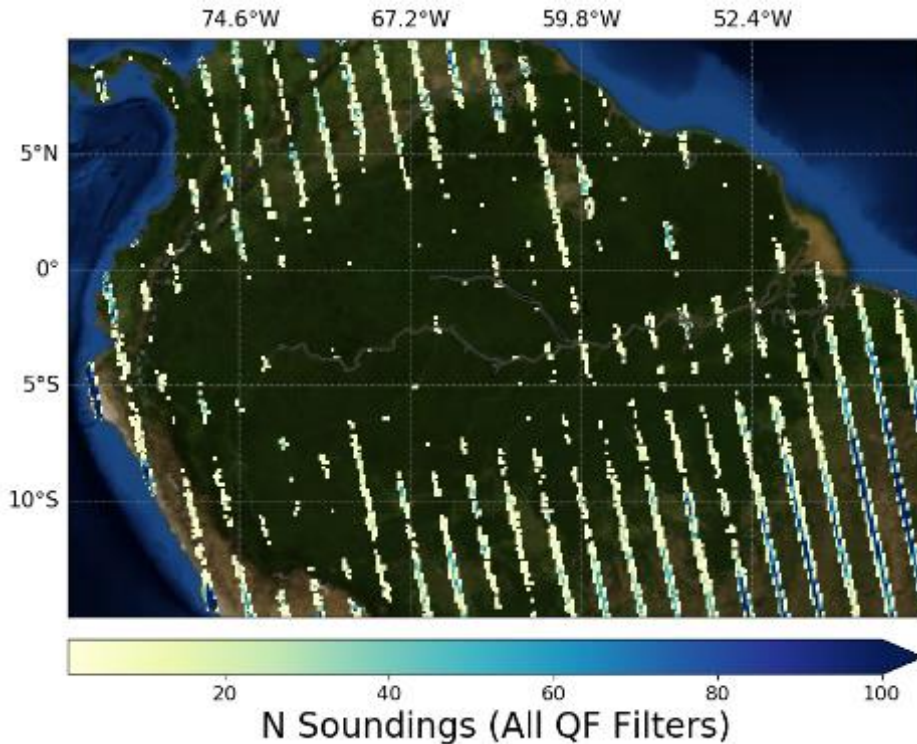
Quality Flagged (B8, latest lite files)

- Rob Nelson has started looking in the low yields over Tropical land
- He found that the quality flag is removing clear-sky dark forest retrievals
- Most soundings are being removed by Amazon being removed by the **strong CO<sub>2</sub> low albedo land filter**
- More later!

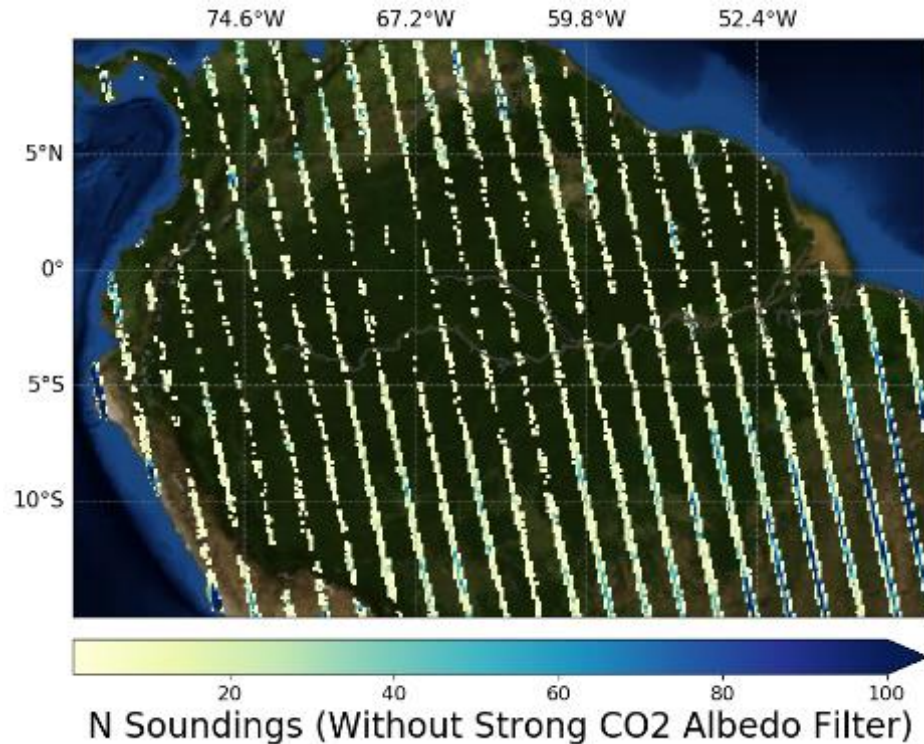


# Getting Amazon Data Back

Rob Nelson



Number of soundings remaining  
after QF is applied



Number of soundings remaining after  
QF is applied (except for SCO2 albedo  
filter)

We may be able to salvage these data in the Version 9 Lite File development

The background image is a wide-angle landscape photograph. The sky is filled with horizontal bands of clouds, ranging from dark, heavy clouds at the top to lighter, wispy clouds near the horizon. The horizon line is low, and the ground is a vast, flat expanse of land, possibly a desert or a dry lake bed, reflecting the warm light of the sun. The colors are predominantly oranges, yellows, and browns, with a hint of blue in the upper sky.

# **Upcoming Activities**



# Near Term Key Planned Activities

Planned Date	Activity Description
2 – 4 May	CEOS AC-VC Annual Meeting, College Park, MD
8 –10 May	IWGGMS (International Workshop on Greenhouse Gas Measurements from Space) in Toronto, Canada
20-24 May	Japan Geosciences Union (JpGU) Meeting in Chiba, Japan
22-24 May	46th Global Monitoring Annual Conference (GMAC), Boulder
3 – 8 Jun	AOGS (Asia Oceania Geosciences Society) in Honolulu, HI
3 – 8 Jun	CGMS-46, Bengaluru, India, (June 8 GHG satellites)
11–15 Jun	2018 NDACC-IRWG & TCCON Annual Meeting, Mexico City
18-19 Jun	CEOS Chair GHG Priority Workshop EC JRC in Ispra, Italy
26 Jun – 2 Jul	2018 Railroad Valley Campaign, Railroad Valley, NV, USA
14 – 22 Jul	42nd COSPAR Scientific Assembly, Pasadena, CA, USA
5-8 Nov	OSA-HISE, FTS, E2 meeting in Singapore